

The University of Chicago

SOME ECONOMIC ASPECTS OF TECHNOLOGICAL CHANGE

A PART OF A DISSERTATION SUBMITTED TO
THE FACULTY OF THE DIVISION OF THE
SOCIAL SCIENCES IN CANDIDACY FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF ECONOMICS
1942

By
YALE BROZEN

CHICAGO, ILLINOIS

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TECHNOLOGICAL CHANGE AND CAPITAL

Capital, except in non-specialized (free) form, is peculiarly vulnerable to technological change. It is embodied in production equipment and in human skills¹ which are fairly specific to the purposes for which they are intended. The value of special purpose equipment and skills is dependent upon the value of the services produced in the specialized operation. If those services become less valuable, then the equipment or skills producing those services become less valuable. A capital loss is the result.

Inventions have a strong effect upon the value of such special services. They may make services more valuable through creating new uses for them. Infinitely more likely, though, is the prospect that they may make services less valuable by creating means of producing them more cheaply or by replacing them completely. It is in this role that technological change has been severely castigated for causing great waste of the available quantity of capital through "unnecessary" obsolescence. Innovations often decrease the quantity of capital by making existing equipment less valuable, and presumably, judging from the alarmed tones adopted by the observers who have called attention to this fact, this is a social waste.

Capital as a quantity may be determined from three different standpoints: (1) what has been put in; (2) what is present at any moment; and (3) what can be got out. The important question relating to technological change is the contrast between the view of capital in terms of what has been put in compared with what is present at any moment (which, of course, depends on what can be got out). If a technical change affecting a particular group of capital goods occurs causing unforeseen obsolescence, the amount of capital as determined by method (2) will decrease and become less than the amount determined by method (1).

With perfect foresight, points of view (1) and (2) are

¹Human skills are produced by investment in education and may be thought of as capital though they are not easily alienated from their owners as capital goods are.

identical under perfect competition. No more is put into any line of investment than can be realized by the sale of the investment. No investment will sell for more than the value present in it at the moment of sale. Only if there is a miscalculation of the value that will be present at any moment does overinvestment occur. Such a miscalculation could be due only to imperfect foresight, e.g., a failure to anticipate changes which, when they appear, reduce the value of the services of the type of durable good in question.

The overinvestment that takes place as a result of imperfect foresight is a mistake in the sense that part of the investment would earn greater returns if it were put into other uses. Because of an invention, or other circumstances, the returns in the particular use to which the investment is put are reduced to below the expected level. The consequent recapitalization reduces the value of the instruments to less than the amount put in.

Does it follow, therefore, that the unforeseen invention causes the waste of capital -- that it would be better not to make the invention? From the point of view of the owners of the capital goods whose value deteriorates as a result of obsolescence, the invention is definitely harmful, but not from the point of view of the economy. It is the error of the owners which causes the waste, not the occurrence of the invention.¹ The failure to

¹This is not to say that the owners did not exercise the best possible judgement under the circumstances. They have made an error not in the sense that better judgement could have been exercised under the circumstances but in the sense that a better decision could have been made if more information were at hand. An important part of any program for increasing the net benefits to be derived from inventions (for decreasing losses due to errors of this variety) would be to make better information available.

It might still be argued that if the invention were not permitted to come into use until plans were readjusted, no loss to investors would occur and therefore it is the appearance of the invention that has caused the loss. Two answers may be made. The first, if the invention is not permitted to come into use, the loss is greater to the society than if immediate use is permitted. The second, investors should be responsible for their own decisions, and especially should be responsible for the decisions which result in losses. It is these very losses which are the incentive for making wise decisions. Preventing or offsetting these losses would result in careless allocation of capital and consequent social losses. When more efficient methods are available, the old should be scrapped and replaced with the new even though losses to individual investors who have made decisions on the basis of imperfect foresight occur. Slowing the introduction of

anticipate the future correctly leads to improper allocation of investment; as soon as capital is committed to such an improper allocation the waste occurs, though it does not become apparent until the unanticipated technical change actually occurs.

Capital is useful only because of the services it renders. From this point of view, it does not matter in the least what amount of capital was invested. Bygones are bygones. The important consideration is the effect of the invention on future income and the size of the future stream of services. If the future income stream is swollen by the invention, it is desirable and cannot be censured upon any economic ground. The total amount of capital may be decreased; the total income going to capital owners may even decrease; but a compensating increase in the productivity of labor will take place which will at least maintain the income of the society. This will be true even if the technical change is capital-saving and takes place under the most unsatisfactory cir-

efficient methods to prevent private losses results in larger social losses even aside from the deleterious effect on incentives. Whether or not equipment should be scrapped is a question to be decided in terms of social benefits and costs, not in terms of private benefits and costs of the individual investor except where these are identical with the social interest. This is not to say that society is an "organism" more important than the individuals who compose it, but rather that some individuals who happen to be investors in equipment made obsolete by the appearance of an invention are not necessarily more important than the individuals who would benefit from the utilization of the invention.

Also, inasmuch as these investors could have behaved in ways which would have avoided losses from obsolescence, they cannot expect to be saved from the consequences for their "misbehavior" if they wish to retain the right to direct their own behavior. True enough, there are many cases where investors have exercised the best of judgement and their activity would not be called an error in the light of what anyone exercising his best judgement would have done in the same situation. However, there is no possible way of distinguishing these cases from those in which "errors" were committed without actually becoming a maker of decisions in the same circumstances, in which case the investors cannot justify their social usefulness or their right to make decisions if some judging body always has to do the same work. In addition, compensating investors for these "errorless errors" would remove the basis for the selection and motivating of the men who do much to reduce the losses to the society from uncertainty. Entrepreneurs (and speculators) make decisions and take risks, and they reduce the losses from uncertainty by specializing in doing these things since they are able to predict the future more certainly than the non-specialists in this function. At least, those who survive and carry on entrepreneurial activities do, for otherwise they would soon fail in their occupation since success depends on superior ability to predict the future and shape economic activities into conformity with their predictions.

circumstances possible. Even under this extreme there will be positive benefits from the invention¹ unless cobweb and acceleration mechanisms or monetary reactions bring about consequences which more than offset any benefits.

A capital-saving technical change can reduce the return to capital only by being put into use and increasing the supply of capital services to the point where price is forced down. The total income going to owners of capital would decrease, but an increased supply of capital services in use with the same amount of labor services would increase the national income. The community benefits, therefore, even though the invention may decrease the quantity of capital² and the productivity of capital.

These effects are clearly brought out by demonstrating the income and distributional changes graphically with a Clark diagram. Figure 1 shows the shift in the marginal productivity curve of capital from P to P' as a result of the capital-saving invention, the decrease in the quantity of capital from OC to OC' because of the failure to anticipate the invention, and the decline in the rate of return from Oi to Oi' . Despite this, the total area under the curve representing the national income has increased since ADA' exceeds the increment lost from the old area. The income going to labor has increased from ABi to $A'B'i'$, and the income going to capital has decreased from $OCBi$ to $OC'B'i'$.

The quantity of capital will not decrease enough, as a result of a capital-saving invention, to raise its marginal productivity on the P' curve above the old level on the P curve. The reason for the decrease in productivity is the increase in the amount of capital available to other uses. This was the result of the invention making less capital necessary in the processes

¹N. Kaldor has pointed out that "the adoption of technical invention itself can never diminish the purchasing power of the community as a whole; and it can only diminish the value of its capital in so far as it increases the value of labour." "A Case Against Technical Progress?" *Economica*, XII (1932), 195. This must be taken in light of the statement that "to blame Technical Progress for a lack of adjustment due to rigidity is putting the cart before the horse." *Ibid.*, p. 196. Also, certain conditions of competition or monopoly must prevail if the community's purchasing power is to remain unaffected by an invention. Otherwise, uneconomic inventions from the social point of view may be applied.

²The conventional language used here is not accurate, as has been pointed out above. It is not the invention which decreases the quantity of capital but the error in foresight.

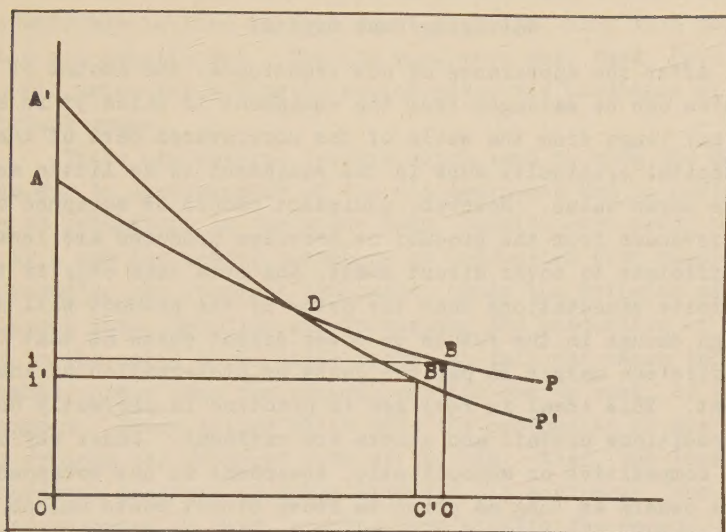


Figure 1.

affected; capital was released to other uses causing the decline in productivity. If all the capital formerly in the affected use were completely specialized to the use, if the price of its services were to drop to the new level that will prevail in the long run immediately upon announcement of the invention (which depends upon the demand for its services being completely inelastic), and if the invention was unforeseen, the quantity of capital would decrease by an amount which would leave its productivity at the old level as a result of the invention. Actually, the price of the services of the old equipment would not drop instantaneously, which means that some capital could be salvaged to be put to other uses as well as enough to provide the new variety of instruments. We have been assuming, of course, that the demand and income elasticities are not great enough to keep the former amount of capital in use in the affected industry in the long run. Otherwise the P' curve would not have dropped below the P curve.

Salvaging Sunk Capital

After the appearance of new techniques, the amount of capital which can be salvaged from the equipment in which it is embodied may range from the whole of the unrecovered part of the total capital originally sunk in the equipment to as little as only the scrap value. However, equipment should be scrapped only if the revenues from the product or services produced are less than sufficient to cover direct costs, and even then only if there are definite expectations that the price of the product will never rise high enough in the future to cover direct costs at that time with sufficient margin to pay the costs of preservation of the equipment. This ideal is realized in practice if perfectly competitive conditions prevail and owners are rational. Under any condition, competitive or monopolistic, equipment is not scrapped by rational owners as long as price is above direct costs unless new equipment can be procured which is able to produce the product at an average total cost less than the average direct cost of producing with the older equipment.

Equipment is not made completely valueless, except for scrap purposes, by the appearance of a new technique unless the new method reduces cost of production to a level lower than the average direct cost of production with the old method and, in addition, the equipment is not usable with the new method.¹ Even after technical knowledge fulfilling these conditions appears, the old equipment will have appreciable value in use above scrap value for a while unless the new technique can be put into full use as soon as it appears. Ordinarily, however, even partial use of the new technique has to wait until certain necessary investment items are constructed, and full use may have to wait a good deal longer than the gestation period.

The old equipment will have some economic worth as long as the price of the product it produces stays above the minimum average direct cost of producing with the old equipment. Only

¹"A new process usually calls for changes in the forms and attributes of productive agencies and necessarily involves new combinations among these. In very simple cases, however, little may be involved beyond new manipulation of old things." F. H. Night, Risk, Uncertainty, and Profit (Boston: Houghton, Mifflin, 1921). p. 340.

added production from the use of the new method will force price below this level, and that added production has to wait until the necessary specialized capital items that are used with the new method are constructed. The old equipment may, then, have some economic value for a lengthy period after the invention of more efficient means.

There are several factors which tend to slow the fall in value due to obsolescence of the old equipment and to postpone the time of relegation to the scrap heap, despite even ready availability of a new and better technique of production with physical means of producing the required equipment. Only the bringing of new equipment into operation and increasing the production of the product to the point where price begins to fall can cause the decline in value, other than the natural decline due to wear, of the old equipment. Those things which slow the production of new equipment prolong the economic life of the old. Also, the less durable the product that was produced with the old equipment, the smaller the inventories on hand, and the more elastic the demand, the longer the price will persist near its old level for any given rate of production of new type equipment. The more slowly the price falls, the longer will be the period available for salvaging the capital sunk in the now rapidly becoming obsolete equipment.

If the price of the product falls slowly, very little of the sunk capital need be lost despite the appearance of the unexpected invention causing obsolescence. If the invention were expected and certain relevant conditions adequately foreseen, the amount of equipment on hand suitable only to the former method would be such that all the capital sunk could be salvaged by the time price falls to the level that makes operation of the old equipment uneconomic.

Assuming an unexpected invention appears, threatening previously existing equipment with obsolescence, what can be done to salvage the sunk capital in this equipment? There is no need to take any special measures if the age distribution of the equipment is such that an equivalent quantity of it wears out as rapidly as new equipment becomes available. The total quantity of product produced per time interval would, under these circumstances, vary in a way which would cause price to remain unchanged until the last piece of former equipment wears out, assuming that the prevailing price was the price which would just cover depreciation

costs if maintained at a uniform level until direct costs of operating the equipment rise to equality with revenues received, i.e., would remain at a uniform level until the equipment wears out.

The usual price behavior in the affected industry might be one of a pattern of fluctuation rather than uniformity. In this case, or in the above case, the amount of equipment constructed on the basis of this known behavior of the price of the product would be such that over the life of the equipment, an amount of revenue in excess of direct costs¹ would be received which would return the capital invested plus an amount equal to that which could have been earned by investing the capital in any alternative use. In terms of ability to recapture sunk capital after new equipment appears, this would mean a price behavior pattern subsequent to the appearance of the invention such as to return an amount of revenue in excess of direct costs so that when added to that already returned, it will equal the amount calculated above. This pattern might be either the precise price behavior that had been expected or some equivalent pattern of price behavior which fulfils the condition of providing enough revenue in excess of direct costs.

Price behavior of this variety following an invention would not occur unless the invention and relevant demand condition were perfectly forecast and investment planned accordingly or unless a

¹Direct costs over the life of a piece of equipment is not the same thing as the direct costs of a given moment or given time interval within the life span of the equipment. In a small time interval, the direct costs include the costs of complementary services used with the equipment and the present value of the future net revenue given up in using the equipment in the present time interval instead of in some future time interval. This latter portion of direct costs has been called "user cost" by Keynes in his "Appendix on User Cost," The General Theory of Employment, Interest, and Money (New York: Harcourt, Brace, 1936). Keynes describes user cost as determined by the "expected sacrifice of future benefit involved in present use" and defines it "as the reduction in the value of the equipment due to using it as compared with not using it, after allowing for the cost of maintenance and improvements which it would be worth while to undertake and for purchases from other entrepreneurs" (p. 70).

One part of direct costs is always the amount that could be earned in an alternative use. If the best alternative use is a use sometime in the future, then the discounted value of that future use quite obviously belongs in the calculation of direct costs. If we are calculating the direct costs over the life of the equipment from a point before the time of its construction for the purpose mentioned in the text above, then the only direct costs that concern us are the costs of complementary services used with the equipment.

combination of happy accidents occur. If the planned life of any of the units of old equipment extends forward into the time after the appearance of the invention when price of the product falls below direct costs, or even into a time when price falls below the expected price on which plans were based, then sunk capital cannot be completely recaptured, assuming no offsetting unexpected price behavior has occurred or occurs previous to the price movement caused by the invention. If the new variety of equipment can be, and is, produced more rapidly than equivalent amounts of the old variety wear out, then price declines will infringe upon the amount of capital that can be recaptured by the owners of the old equipment in the face of these unexpected conditions.

However, even though these conditions prevent the complete salvage of the capital invested, a good deal may be saved by speeding the rate of operation of the capital goods to a level above that which had originally been planned. If price is in excess of marginal direct cost, aside from marginal user cost, the amount of present returns in excess of direct costs aside from user cost may be increased through an increased present rate of operation. The capital invested would be converted into a free form more rapidly under this plan, and less would be left in a form which will be rendered valueless at a later date through the wide application of the invention.

Ordinarily, the rate of operation would not be at the high level recommended in the capital salvage operation discussed above since such a rate would decrease future returns more than is compensated by the rise in present returns. The equipment wears more rapidly at high rates of operation and average non-user direct costs are higher, thus reducing net returns and causing operators to refrain from high rate output. Lower rates of operation are preferred since the increase in future returns are greater than the amount of present returns sacrificed. Once operators become aware of a threat to future returns, e.g., the prospect that the introduction of a less expensive method of production will lower the price of the product, they will increase production rates since there is no longer any reason for sacrificing present returns. There is no longer the possibility of greater future returns to offset the inducement of present returns.¹

¹"The stream of new mechanical inventions, which hasten

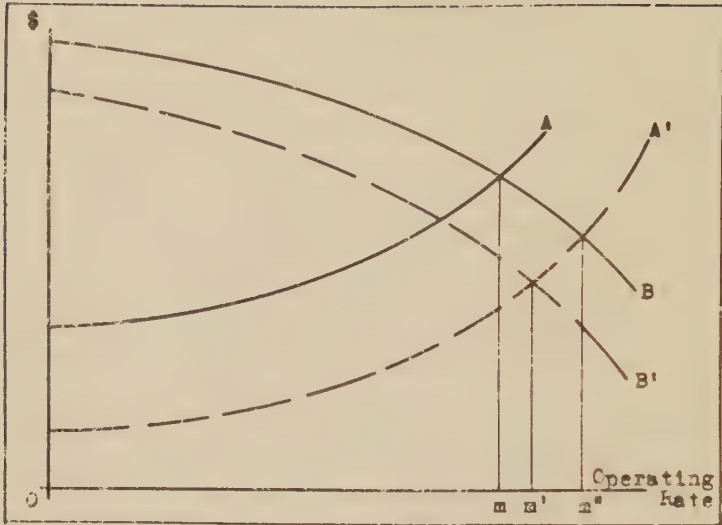


Figure 2.

The effect upon the present rate of operation may be demonstrated graphically. Turning to Figure 2, curve A represents the present value of future returns given up for each unit added to the present rate of operation. Assuming for purposes of simplicity that every unit of future returns given up occurs at the same point in the future, the curve would be a horizontal line, abstracting from any changes caused in maintenance costs by differing present rates of operation and assuming constant marginal costs. If it is assumed that the future rate of maintenance costs per unit of output is increased by exceeding a critical point in present rate of operations, which is a reasonable assumption from an engineering standpoint, curve A will tend to slope up beyond this

the obsolescence of machinery in manufacturing generally, encourages more intensive working than before in order to wear out equipment before it is obsolete." S. C. Gilfillan, "Social Effects of Inventions," Technological Trends and National Policy, Report of the Subcommittee on Technology to the National Resources Committee (Washington: U. S. Government Printing Office, 1937), p. 26.

critical point.

The amount of future returns per unit represents the difference between price and marginal cost at the time the unit is produced. If the marginal cost curve is upward sloping in the relevant range of operations, and if it is assumed that a higher present rate of operation necessarily means a lower future rate of operation and consequent lower marginal costs, then future returns sacrificed for each extra unit produced at present are greater, the greater the present rate of operation. The curve (A) would slope upward in the whole relevant range under the latter assumption. Even aside from this assumption, if we drop the assumption that all future production occurs at the same point in time, then the curve will have an upward slope because each unit increase in the present rate causes the sacrifice of a nearer unit than the previous unit increase causes, under the usual conditions. The future return sacrificed is subject to less discount and has a higher present value for each unit added to the present rate of operation.

Curve B represents the amount of increase in present revenue above direct non-user cost resulting from a unit increase in the present rate of operation. The increase in present net revenue, assuming perfect competition, is equal to the price per unit minus marginal non-user cost. If marginal cost increases with output, the curve will be downward sloping.

The intersection of curve A and curve B will determine the economic rate of operation. That is the point where any increase in the rate of operation would cause a sacrifice of future net returns so great that their present value exceeds any increase in present net returns. For this reason, it does not pay to increase the present rate of operation beyond O_m .

The announcement of the availability of a more efficient technique of production which had not been anticipated will cause curve A to fall to the new position A' and curve B to the new position B'. Curve A falls because the anticipated future price is now lower than had previously been expected. This causes the rate of operation to tend toward O_m'' . As the rate of operation of all old equipment in all firms is increased, supplies offered in the market are appreciably increased causing the present price to decline and curve B to fall to the position B', limiting the rate of operation to O_m' .

Inasmuch as the price has fallen, new equipment will not

be introduced as rapidly as it might otherwise have been. If the invention had been correctly anticipated, less capital would have been invested in the old equipment and there would have been a larger market for new equipment. This is expressed graphically in the fact that curve A will not move downward as rapidly as it might otherwise have done, though it will start moving downward as new equipment is introduced from a lower position after the announcement of the invention than would otherwise have been true.

When curves A and B fall low enough so they are in the zero or negative region of the graph, the piece of equipment whose condition they represent is worthless. All old equipment does not necessarily become worthless at the same time. Curves A and B differ for each piece of equipment, depending upon the age of the individual piece and the state of repair.

The old equipment should be scrapped when the minimum average direct cost of operation (including interest on scrap value of the equipment) comes to equality with price and tends to exceed it, and the amount of future net returns is zero or less. These conditions are indicated by curves A and B falling into the zero or negative region of the graph. The greater the rate of operation of the old equipment, the sooner this will take place because the direct non-user costs will rise more rapidly through time. The greater rate of operation will be undertaken after the appearance of an unexpected invention to enable owners to salvage more capital from their equipment before the time of zero operational value arrives. This will maintain the quantity of capital, measured in social or private terms, at a higher level and minimize both social and private losses from the misallocation of capital resulting from the fact that the time of appearance of the invention could not be predicted with complete accuracy.

The Optimum Use of Capital

To indicate with precision the effects of any given invention upon the quantity of capital, the marginal productivity of capital, the income of the community, and its distribution, it is necessary first to set up a standard of measurement. The standard will be a community in which the economic mechanism allocates capital perfectly in a situation with no technological change, first with no risk present, then with risk present, and then with uncertainty present. Then the successive complication of technological

change with perfect foresight, innovations with only an actuarial knowledge of their incidence, and finally completely unforeseen technological change will be introduced under the assumption that once a technical change occurs, perfect adjustment will be made to it. The consequences of these various kinds of disturbances will be compared with the standard, and the good and bad effects analyzed. The effects of these disturbances in the present society, whose economic mechanism does not make perfect adjustments to changes in technology, will be reserved for later analysis.

Allocation of capital in the absence of risk.--The problem of allocation of capital is that of determining which uses will yield the greatest return per dollar per year. To produce the greatest social benefit, increments of capital should be assigned to those uses in which they produce the most valuable product increments. Under perfect competition, entrepreneurs will bid as high as the value of product increment to obtain the use of capital. The highest bids will be made by those who have uses available in which capital produces the greatest value of product increment. Since the owners of capital will sell its services to the highest bidders, capital will go into the best uses -- assuming the value of product increment to a perfect competitor is the same as to the society, and it will be under properly framed property laws -- and the interest rate will be bid up to equality with the value of product increment.

With no risk present, the value of the product increment produced in each use will be easily determined. Capital owners will be indifferent as to whether they hold bonds, preferred or common stocks, partnerships in the enterprise using their capital, or direct titles to durable instruments leased to users on a rental basis. The returns on each would be definitely known and equal and the only problem in choice of form would be to choose the one which receives the greatest social approbation and is subject to the minimum legal fees.

Allocation of capital in the presence of risk and the social cost of risk.--With risk present, entrepreneurs are able to obtain some of their needed capital at rates which appear to be below those that can be earned in other uses. They can do this because they are able to offer contracts which have some of the characteristics of money, or which are more riskless than other forms of investment contracts current. These characteristics are

sufficient inducement to owners of capital to make them willing to accept the apparently lower yield on these contracts.¹

The consequence of the acceptance of greater risk by the holders of junior securities is that, in some periods, they will receive less than is paid to the holders of senior securities and less than they would otherwise have received, in other periods, more. The average return will tend to differ in the long run from that of the senior securities only by an amount sufficient to pay the greater cost of selecting risks among the junior securities and the losses due to the temporary non-availability of income at times from the junior securities, assuming there is no repugnance to or special desire for risk-taking in the community as a whole. Any actual positive difference that does exist at any time between yields of different classes of securities may be regarded as an insurance premium paid to equity owners to assume the accentuated risks shifted onto the junior securities from the senior securities; a negative difference at any time may be regarded as payment of a claim for loss on the insured risk; a positive difference

¹The contract which carries no rate of interest is perfect money and is the standard against which the yields of other forms of contracts are measured. The yield of money provides the zero level for the calculation of the rate of yield of other securities. This does not mean that money is a riskless investment or that absence of risk in any investment contract would reduce the rate of return to zero or give it the characteristics of money. We are simply taking the yield on money as the arbitrary zero from which rates of return on other investments are measured. This arbitrary zero may be above or below the absolute zero.

The contracts which have some of the characteristics of money are not necessarily more riskless than other contracts. Usually, where money itself is more riskless than most investment contracts, the near-moneys are more riskless than other forms of investment. At times, particularly in periods of political instability, many forms of investment are more riskless than money. In these times, there is not only the usual inducement of the higher returns offered on investment other than money causing money-owners to convert to other forms of investment but also the diminished chance of loss, assuming the political instability is of the form skewing risks of holding money to the loss side but leaving unquestioned the institution of property.

The notion that money may be held in order to obtain certainty is simply not true, except insofar as it is held in a balanced portfolio. It is true that there is a choice between holding money and holding other investments, but the liquidity of investment contracts compared with the liquidity of money is not as determining a factor in this choice as the disciples of Mr. Keynes would have us believe. Neither is the rate of interest offered on investment contracts.

over the long run may be regarded as the cost to preferred holders (the insured holders) of buying insurance or the payment to residual owners for providing insurance; a negative difference in the long run may be regarded as the payment to the insured by the junior holders for the pleasure of taking the risks.

Inasmuch as the marginal yield of capital subject to the discretion of entrepreneurs financing themselves by mixed security structures turns out no less and no greater than that of other uses available, such means of capital raising do not cause misallocations but simply redistribute the burden of risk. Inasmuch as any lower yield does result, it means that some consumers have had to accept less desirable services than could have been made available to them. If such security structures reduce the cost of risk to the society by a compensating amount, however, then the losses to the consumers of capital services will be offset by the services released from expenditure on the bearing of risk.

Even if the costs of risk are not reduced, the owners of capital may derive enough increased satisfaction from the security of their position to make such allocations worthwhile. Assuming there is no more inexpensive way to the society of providing comparable security to capital owners (there are institutional methods of lessening risk without resorting to poorer allocations of capital), the allocation cannot be quarreled with except on the grounds that the ownership of capital should not be distributed in the way it is. It is likely, however, that any more equal distribution would increase the amount of capital seeking to avoid risk by going to worse allocations where risk (and uncertainty) is not so great, since large groupings which cancel local risks against one another would be broken up. From the overall point of view, capital is put to the best use when it provides the highest net value of product increment including the value of the satisfaction of security to the owner, and that is the optimum allocation in line with the current distribution of wealth and income.

The non-defaulted securities of any type of enterprise in a field which has a higher anticipated percentage of losses will pay a higher rate of return than securities in completely riskless fields. Assuming local uncertainties exist, but over-all certainty, the average rate of return in each field of investment will be the same, though some investments in a given field may pay locally higher returns. These locally higher returns may be re-

garded as an insurance premium paid to investors to guarantee that their average return in the given type of investment will be equal to that obtainable elsewhere.¹

Despite the apparently higher returns earned in some enterprises seeming to indicate a better use available to capital, the allocation of capital is correct if these higher returns are just sufficient to offset the losses that occur which must be chanced by investment entering the given field. To put more capital into the riskier industry or riskier type of enterprises would take capital from uses affording an assured rate of return to be put into others where the return may be higher, but may also be lower. From the social point of view there is no value gained since benefits from any successful extra investment will be more than offset by unsuccessful extra investment on the average. If investors are tempted by the chance of higher returns to carry their investment in the risky field to the point where the average return turns out below that which could have been earned elsewhere, consumers will have to take less services than they might otherwise have received, but the investor may gain in the satisfaction of his gambling pro-

¹It must be remembered that there are factors militating against the same precision in the allocation of investment to eliminate risk on this insurance principle as insurance companies who operate on known actuarial distribution in eliminating risks are able to attain. "... while the principle of canceling and of insurance do apply widely, there is no possibility of making any substantial provision against the major risks of a business. Business decisions embody an effort to predict and control the course of events in a particular case, and the liability to error in foresight and in action differs in principle from the ideal of a probability situation. Not only is it impossible to group such decisions into classes approximately alike from the probability standpoint, but they are subject to a complicated and vital moral hazard. . . . The motivations involved in making commitments on the basis of one's own judgement are very different from those involved in gambling on a mechanical probability. Actual gambling may of course be connected with an exercise of judgement, real or supposed, as when one picks the winner of a horse race; but the motives are still very different when the bettor himself is the runner. Similar considerations apply when personal relations are involved, as when one 'bets' on his judgement of collaborators in an enterprise, selected and directed by himself. It becomes therefore quite impossible in the case of business risks to assert on any objective ground that there is even approximately a certain fractional 'chance' of any particular result; an assertion in this form merely expresses a certain degree of confidence or belief on the part of the person who makes it and rather accidentally resembles a statement of a certain quantitative probability." F. H. Knight, "Risk," Encyclopaedia of the Social Sciences (New York: Macmillan, 1934), XIII, 394.

pensities. Investment in education for the legal profession is notorious in this respect. Once again, however, such allocations are correct unless undertaken in ignorance rather than in hope.

If the anticipated percentage of losses in any given field turns out incorrect, and the amount of investment in each use was carried to the point where the anticipated return to the last increment in each use was equalized, then there will have been too much or too little investment made in that field depending upon whether the rate of return turns out to be below or above that which could have been made in other uses. Error in forecasts can cause losses in this way, and it is for that reason that care must be exercised to make the best possible predictions. After making the best possible predictions, investment must then be allocated to give the maximum insurance at the least cost against the inaccuracy of the predictions. The cost beforehand will be the anticipated reduction in the average rate of return, which should be zero, plus the costs of selection of risks. The cost determined by hindsight will be the actual reduction in the rate of return due to the allocation that was made compared to the one that could have been made if there had been better foresight. If the only losses that occurred were truly due to chance causes which could have struck any item of investment, the hindsight cost will be zero.

The degree of perfection of foresight (degree of coincidence with hindsight) depends, in part, on how much of the information relevant to prediction is gathered that could be gathered. The decision maker has to predict how much his predictions can be improved by additional expenditure on information gathering and carry expenditure to the point where additional expenditure is not expected to bring a sufficient increase in returns due to better prediction to pay for the additional expenditure.¹ If, by hindsight, the decision maker sees he could have allocated the capital he controlled to the group of uses surveyed in such a way as to bring a higher return, but if the cost of gathering information necessary to better predict the probability of given returns in

¹"The question is complicated by the fact that the use of resources in reducing uncertainty is an operation attended with the greatest uncertainty of all. If we are uncertain as to the results of ordinary business operations we are doubly so as to the results of expenditures along any of the lines enumerated looking toward the increase of knowledge and control." F. H. Knight, Risk, Uncertainty, and Profit, op. cit., p. 348.

any of the uses would have been greater than the increase in returns, then the cost of insuring a given return is zero. If the return could have been increased by an amount greater than the cost of improving the basis of prediction, then the cost of insuring the returns obtained is the difference between the possible increase and the additional cost of better prediction and selection.

Effects of optimism and pessimism in risk-taking on the allocation of capital.--Errors in foresight which are due to an optimistic prediction of the length in time of an income stream from particular instruments tend to be more costly than errors (measured by number of years mistake in prediction) due to a pessimistic prediction. In the former case, if the income stream vanishes, the capital put in the instrument and not yet recovered is lost. In the latter case, the capital is available to be used once again though it may have earned a lower return than it might otherwise have earned. Since the costs of optimistic uncertainty concerning durability of an income stream tend to be greater than those of pessimistic uncertainty, investors who are aware of these chances prefer the pessimistic attitude. This attitude leads to the choice of instruments of shorter durability. Such an attitude is a stabilizing factor in the economy, assuming it does not lead to untoward monetary repercussions. The costs of instability are so great that the lower returns may be more than compensated by lower costs of instability.

In respect to other types of chance taking, optimistic uncertainty takers may be defined as those who are willing to take small chances of very large gains and large chances of a loss, and pessimistic uncertainty takers defined as those who prefer a large chance of a small gain to a small chance of a large gain. The difference is expressed in part in the kinds of investments made, in part in the amount of investment put into any single use. The optimists invest in new industries, in industries which show a large percentage of failures and some conspicuous successes, and in junior securities. The pessimists (conservatives) invest in the stable, developed industries and in senior securities. The optimists bet large sums on a single roll of the dice. The pessimists spread their capital over many rolls, betting a small sum on each roll.

Society needs both kinds of uncertainty takers. Without the optimists, there would be little progress. Without the pes-

simalists, there would be little stability.¹ If everyone were optimistic (or if there were too many optimists), capital would probably be misallocated, the average return in the long chance uses falling below the average return in the certain return uses. If everyone were "conservative," capital would again be misallocated, the average return in the certain return uses falling below the average return in the long chance uses.

A few fence sitters are needed, also. If too many optimists begin to appear -- if the average return in long chance uses begins to fall compared with the certain return uses -- the fence sitters move into the "conservative" camp, thus offsetting the tendency toward over-investment in the long chance uses. Similarly, they compensate for the appearance of too many conservatives.²

This differentiation between optimists and pessimists is pertinent in a society in which the great majority of investors do not possess large enough quantities of capital to be able to reduce uncertainty (and risk) to the vanishing point for the group of investments owned by the single person. If enough individuals possessed very large aggregates of capital, they could be of conservative temperament and still not be unwilling to invest in uses where there are large chances of loss and small chances of very

¹J. Akerman, Economic Progress and Crisis (London: Macmillan, 1932), pp. 92-7.

²The institutionalization of investment in its present forms (insurance companies, trusts, banks) in which fixed claims are given in return for contributions to the capital pool is giving the society more "conservative" investment (though not truly conservative inasmuch as the chances of a fall in the value of fixed claims is not properly hedged) than can be offset by the number of fence-sitters available.

The notion that fixed claims and money are the refuge of those who are seeking a "safe" or "certain" investment is probably the greatest single fallacy in both lay and professional economic thinking. Properly used in a balanced portfolio of investments, fixed claims and money help insure that a certain average return will be earned. They provide against the contingency of a fall in prices while other parts of the portfolio provide for other contingencies. Investment of a major part of a portfolio in money or equivalents is not to provide for uncertainty -- a balanced portfolio is required for this task -- but is to take advantage of a special sort of certainty concerning price movements just as inclining a portfolio toward junior securities or some other special use is to take advantage of certainty concerning other things. Cf. J. R. Hicks, "A Suggestion for the Simplification of the Pure Theory of Money," Economica, II n.s. (1935). Money hedges uncertainty only if flexibility best does this and the cost of "getting out of" money is less than "getting out of" other assets.

large gain. By investing in several such uses a given return could be assured with sufficient probability to satisfy conservative individuals. The reduction in the number of such individuals, however, has increased the necessity for a large number of optimistic investors.

Problems in the Allocation of Capital

To allocate resources properly to their various uses, or to be able to bid for resources under perfect competition, the value of the product increment that will be produced by a unit of the resource must be predicted. The determination of the value of the product increment, e.g., of the interest rate in the case of capital, is not as simple for a productive service such as capital as it is for one such as labor. There is a problem of futurity involved since the services of capital cannot be used for any short period without committing it to a specialized use involving the risk of changes in the value of that use during all the time the capital is committed to the necessarily specialized form.

To determine the interest rate that can be earned in any particular use, the cost of the capital good (we include in capital goods skills acquired by investment in education) and the shape and size of the future income stream to be derived from the rental or direct use of the capital good must be known. Knowing these things, the interest yield for the particular use may be determined.¹ The market interest rate will then be determined by the marginal use to which the last increment of free capital may be put.

Investment in any one use will be carried to the point where the cost of producing another unit of durable good is equal to the discounted income stream expected, the rate of discount being the rate that could be earned by turning the investment to alternative uses. The more investment is put to any one use, the lower the rental value of the durable good will drop through pressure of the increased supply on the market. As long as the discounted income stream is greater than the cost of producing the durable good, more of the durable good will be built until the cost and discounted income are brought into equality by the decline in

¹See F. H. Knight, "The Quantity of Capital and the Rate of Interest," Journal of Political Economy, XLIV (1936), 401-50

rental value and the rise in cost of producing the durable good and perhaps even by a rise in the interest rate to be earned in other uses if the particular use is important enough to attract sufficient capital from other uses to cause this.

The alternative uses available to capital include not only the option of producing various kinds of services, but also the option of producing those services at different points in time. Capital may be used to produce more of a given kind of service next year, or it may produce less of that service next year and instead produce more the following year. Inalienably bound with the choice of the kind of service to be produced is the choice of the time at which the service is to be produced. Both choices must be made at the time that capital is committed to a specialized form, though the choice is not necessarily determined for once and all. Once committed, the capital becomes very illiquid, being available only to the use or a narrow range of uses for which it was intended at the time the instrument embodying the capital was constructed. If this use or range of uses becomes less valuable, the instrument becomes less valuable unless it can be switched to other equally valuable uses at no cost.

Whether or not part or all of the value of an instrument intended for a particular use can be resuscitated, when the worth of that use diminishes, by putting it to alternative uses depends upon the initial manner of construction of the instrument. Providing for alternative use is expensive. Returns have to be sacrificed to guarantee against the risk of diminution in future returns to a particular use. If the future is perfectly foreseen, in an actuarial sense, the amount of such risk is known and can be definitely insured at a known cost, either through diversifying investment together with grouping or through constructing instruments intended for particular uses in a less specialized form, whichever is less expensive.¹

¹We are here concerned with the more common methods of reducing the uncertainty of return to capital instruments. Knight has written an admirable paragraph summary of the methods of dealing with uncertainty, including the two mentioned above, in his Risk, Uncertainty, and Profit, *op.cit.*, pp. 239-40, which is here reproduced. "We may call the two fundamental methods of dealing with uncertainty, based respectively upon the reduction by grouping and upon selection of men to 'bear' it, 'consolidation' and 'specialization,' respectively. To these two methods we must add two others which are so obvious as hardly to call for discussion:

The usual choice affected by risk considerations is that of choosing between constructing instruments giving a narrower stream of services over a longer period of time or instruments giving a broader stream of services over a shorter period of time. Another choice to be considered is the construction of an instrument fitted to a variety of uses. This involves greatly enhanced cost in most cases and is not worthwhile for that reason, though practically every durable good has a few alternative uses available. Sometimes an instrument can be built so that it may be switched to an alternative use, should the occasion arise, at a cost which need not be undertaken until the necessity of shifting occurs. Such an instrument is relatively more riskless; investment in it will be carried to a point of lower returns than in riskier types, though the difference will be accounted for by the greater costs of undertaking and balancing risks rather than any compensation for risk per se, using risk to mean that an actuarial value is known but that uncertainty in particular items of the group exists.

Allocation of capital and uncertainty.-- If uncertainty as to the actuarial value of the return on other kinds of investment exists, investment in the less riskless field will be carried to a point of still lower returns. The increase in the difference in returns may be regarded as the consequence of repugnance to uncertainty when there is no compensation for it.¹ Assuming that

(3) control of the future, and (4) increased power of prediction. These are closely interrelated, since the chief practical significance of knowledge is control, and both are closely identified with the general progress of civilization, the improvement of technology and the increase of knowledge. Possibly a fifth method should be named, the 'diffusion' of the consequences of untoward contingencies. Other things equal, it is a gain to have an event cause a loss of a thousand dollars each to a hundred persons rather than a hundred thousand to one person; it is better for two men to lose one eye than for one to lose two, and a system of production which wounds a larger number of workers and kills a smaller number is to be regarded as an improvement. In practice this diffusion is perhaps always associated with consolidation, but there is a logical distinction between the two and they may be practically separable in some cases. We must observe also that consolidation and specialization are intimately connected, a fact which will call for repeated emphasis as we proceed. In addition to these methods of dealing with uncertainty there is (6) the possibility of directing industrial activity more or less along lines in which a minimal amount of uncertainty is involved and avoiding those involving a greater degree."

¹"Doubtless in the long run of history there is a tendency

men are attracted by a small chance of large gains and are repelled by a small chance of large losses even though a large chance of small gains is present, the difference in returns between the certain (in the sense that an actuarial value is known) and uncertain fields will be greater when the distribution of possible gains in the uncertain area is judged to be skewed toward the loss side, and will be lessened when the distribution of possible gains is judged to be skewed toward the gain side.

The correct allocation of capital.—Assuming a perfectly riskless world, the durability of instruments will be carried to the point where the increase in cost due to extending the durability of the good another increment of time is equal to the increase in present value due to the extension of the income stream by the same increment of time.¹ In so doing, capital will be taken from uses where it would produce services in the very near future and put to uses where it will produce services in the more distant future. This is a correct allocation,² inasmuch as time preference is equated to the interest rate by the choices made between saving and consuming and the marginal productivity of the more distant uses is equated with the marginal productivity of the nearer uses. The interest rate and time preference being what they are, the capital yields a value of product increment at the future date whose discounted value is as great or greater than the value of product increment it would yield at the nearer date. Such being the case, the satisfaction yielded under the given scheme of distribution is made greater by putting capital to the more distant use.

toward rationality even in men's whims and impulses. And if for no other reason than the impossibility of intelligently dealing with conduct on any other hypothesis, we seem justified in limiting our discussion to rational grounds of action. We shall assume, then, that if a man is undergoing a sacrifice for the sake of a future benefit, the expected reward must be larger in order to evoke the sacrifice if it is viewed as contingent than if it is considered certain, and that it will have to be larger in at least some general proportion to the degree of felt uncertainty in the anticipation." F. H. Knight, Risk, Uncertainty, and Profit, *op. cit.*, p. 236.

¹K. Wicksell, Lectures in Political Economy (New York: Macmillan, 1934), I, 274 ff. R. G. D. Allan, Mathematical Analysis for Economists (New York: Macmillan, 1939), pp. 404-5.

²Assuming the given distribution of income and ownership of capital is accepted.

The introduction of risk will alter the distribution of capital services between points in time in favor of the nearer points, assuming risk of loss is cumulative through time. This allocation will be carried to where the reduction in the cost of risk-taking is equal to the reduction in the expected average return from capital due to the reallocation. The presence of uncertainty in some kinds of investment will mean that the average rate of return will be lower than where there is complete certainty. This follows from the increased expenditure on prediction and selection necessitated by uncertainty, and also from the mistakes that will probably be made. The uncertainty in particular kinds of investment may average out to complete certainty as to the overall rate of return to all investment, yet the average will be lowered by the existence of any local uncertainties.

With any local uncertainties, the productivity of some investment will turn out above average and of others below average. If these uncertainties had not been present, investors would have known what rate of return to expect and would have transferred the less productive investment to the more productive uses thus raising the average. Complete certainty as to the average rate of return may exist, yet the presence of local uncertainties will result in allocations which, in the light of hindsight, turn out uneconomically unless the losses that have occurred are due to the operation of pure chance, and which cause the average return to fall short of that possible with certainty present locally as well as in general.

Risk is always present. It may be known in the actuarial sense, yet it does not seem possible at first glance to reduce the cost of risk-taking to the society or to the individual by reallocation. Diversification and pooling, and perhaps diffusion -- though this latter method seems to aid mainly only in making greater diversification possible, though reduction in amount of single individual losses has some effect in minimizing sacrifices to the members of investing groups in the long run -- seem the only feasible methods of meeting risk and uncertainty in carrying out individual programs of investment. Other methods could be used, e.g., control over the various sources of uncertainty such as technical progress, changes in tastes, etc., but they involve sacrifices in the social welfare in order to increase the certainty of return to individual investors. Risk and uncertainty should not be met

by these methods, nor by reallocation of investment with respect to the allocation for the whole economy.

For the individual, the presence of risk may be met by re-allocating investment to diversified uses in which risks cancel against one another if investment was not so allocated with certainty present. Presumably, some investments get greater than average returns, some less, and by insuring in a pool these cancel against one another and average returns are guaranteed. Reallocation for the individual insures his return. Reallocation for the society in the face of risk and uncertainty would be useful only if it increased the average return. Since the average is insured anyway by the diversification existing in the society, and it is not readily apparent that the average would be increased by reallocation, it is not worthwhile for the society to undertake such a program. If anything, it would seem that reallocation to reduce risk would reduce the average return since the only alternative uses are less productive than those originally chosen.

There are rather large costs attached to insurance for the individual investor, however, though insurance from the over-all social point of view is already provided by the usual diversity present in society. If insuring is done at arm's length, there are sometimes the costs of longdrawn litigation and always the costs of verifying claims. Costs of investigating and selecting risks are present even in self-insurance programs. The greater the risks involved, in the sense of dispersion and skewness of the distribution involved, the more care must be exercised in the selection of risks and the more defaults and salvage operations will have to be taken care of. Consequently, the higher the cost, to the society as well as to the individual, of providing individual insurance. By shifting investment from those places which carry higher risk costs to those with lower risk costs, some return on investment will be sacrificed, but it will be offset by the saving in risk costs.

The farther in the future an income-stream extends, the greater the risk of its being affected since the risk tends to be cumulative through time and the dispersion and the uncertainty are greater at more distant points in time. Because of the greater uncertainty and the greater cost associated with taking greater risks, investment will tend toward the production of the shorter, broader income streams rather than the longer, thinner streams,

and the rate of interest (return on real investment) will tend to be lower than if the future could be more perfectly foreseen at no additional cost.

The allocation of capital in anticipation of technological change.--Inventions influence the investment pattern through their effect on the income stream. The chance that an invention may enhance the income stream from a given kind of durable good through creating more uses for its services will cause more investment to be made in that type of good. It is far more likely that the income stream will be narrowed by an invention, however, for inventions tend either to bring about production of the given service at a lower cost or the production of a new service which replaces the old. The new good or service might be produced with the instruments used in the old process, but it is likely that a new process involving different types will be required to produce the new good. This chance together with the cost-saving type of technical change are both in the direction of narrowing the income stream. Any enhancement of the income stream would be only temporary, anyway, since an enlarged income stream would cause more of the durable good to be produced until the income stream was reduced nearly to its former proportions. The preponderant effect of technological change is to decrease the likely income stream to be derived in the future from any given durable good with only slight compensating chances of an increase. The distribution of risks is badly skewed to the loss side for the more durable goods, and the likelihood of loss increases with the length of time required to recapture sunk capital.

The prospect of technical changes causes capital to be allocated to the type of goods producing short, broad income streams. Removing capital from the more distant uses to more immediate uses reduces the return compared to that which would prevail if there were no prospect of invention, but increases it compared to the return that would prevail if capital were put to more distant uses in the face of the likelihood of technical changes.

It is not to be inferred from this that the prospect of technical changes makes capital less productive. The immediate rate of interest is reduced, true enough. But the future rate of interest may be increased by inventions. Capital is put to more immediate uses when technical changes are likely to occur not only so that it may avoid suffering from a narrowed income stream, but

also so that it may be more quickly recovered and put to the more productive uses opened up by technological change. It is both to the individual and to the social advantage to have capital in the less productive¹ uses temporarily from which it may be quickly recovered to be put to the highly productive uses when they are discovered. If capital were put to longer term uses, then the full use of inventions would have to wait on the recovery of capital, the total quantity of capital would suffer, and the society would lose.

With the likelihood of technical changes, a large present return does not have to be offered to have capital put to the very immediate uses instead of the more distant uses. The advantages of liquidity offset the paucity of immediate returns. With real liquidity the possibility of a large loss is diminished along with uncertainty. Yet the possibility of gains is not completely lost since a quick switchover to the uses made more productive by unforeseen change will get in on the above average returns soon enough to get much of the cream. This of course assumes that investors in liquid items believe they can beat one another to the new opportunities.

The result of the change in allocation of capital to take account of the prospect of technological change.---The result is a greater present consumable income for the community. The marginal productivity and income of labor are increased and the present income of owners of capital decreased by this same condition. Labor has more, though less durable, capital instruments to work with. The stability of the economy is probably somewhat enhanced through the lessening of cobweb, acceleration, and reinvestment cycle effects along with the redistribution of income in favor of those who consume a larger proportion, all as a result of the lessened durabilities.

The effect of anticipated future technical change in terms of the reaction on labor productivity and income is equivalent to increasing the quantity of capital. In terms of the reaction on capital productivity and income, it is equivalent to increasing

¹Less productive compared to the uses which capital could be immediately committed to if there were no technological change, but not less productive compared to the uses created by technological change which the capital can be put to if it is free at the time the use becomes known.

the quantity of capital without the owners of capital having an increased number of units of capital to yield them an income.

The Control of Technological Change

Knowing the effects of inventions, it is evident that the possession of knowledge of what particular inventions will occur would save quantities of capital. Imperfect foresight results in subjective valuations of investment opportunities which exceed (or fall short of) the objective valuations and thus cause overinvestment (or underinvestment). Capital is invested in some types of equipment which should have been put to other uses, either other types of equipment and/or less durable forms of the same type.

With more perfect foresight, fields in which higher returns would otherwise prevail would have more investment put into them; the fields in which losses would otherwise occur would not suffer overinvestment. New techniques need not decrease private valuation (subjective valuation) of capital items whose services are reduced in value if the appearance of the new techniques has been anticipated sufficiently far in advance. Where they do reduce these private valuations, the reduction is properly attributable to imperfection of foresight -- i.e., the capitalization of assets on the basis of returns which are not realizable or the construction of assets in anticipation of a larger income stream than will actually occur -- and not to the appearance of the unforeseen invention.¹ To the individual investor, the progress of technology must be accepted as an invariant -- a factor to be taken into account but not to be controlled.

Once an investment is made -- once capital is committed to a specialized form -- no good can accrue from delaying the introduction of an invention which threatens the value of the investment. There is nothing to be done except to operate the equipment at the rate determined by the type of analysis used above. The application of technical changes increases the income of the community, and it is that which is important.

Slowing the rate of introduction of new equipment in order

¹" . . . to count the loss to these owners, in respect of any unit taken over from them by the new machinery, as a part of the social cost of producing that unit would be incorrect." A. C. Pigou, Economics of Welfare (4th ed.; London: Macmillan, 1932), p. 189.

to salvage all capital put into old equipment would result only in wasting the complementary services used with the older equipment and in forcing consumers of the product to save for the benefit of the owners of the obsolete equipment, turning the savings over to the owners through the higher prices maintained by slowing the introduction of the new technique.

Though the amount of capital salvaged after the appearance of an invention might be less than that originally invested where imperfect foresight has resulted in overinvestment, from the social point of view the difference could be made up, and probably would be, by saving and investing the services of the resources saved by the invention, increasing capital to its former quantity. At the same time, an increase in consumption could be permitted instead of forcing the decrease usually necessary to make additional investment possible. Such a decrease would not be necessary in this case because of the increased production made possible by the invention. Even if the whole amount of resources saved by the invention is used to produce consumers goods, and even if the quantity of capital is permitted to fall below its old level (assuming for the moment that no net saving is being done from any other source of income), the quantity of capital remaining will be sufficient to produce the former quantity of product since it now has the aid of a new technique.

This will become apparent if a few simple points are brought out. First, the quantity of capital in the old equipment declines below the level of that put in only because of a decline in price of the product to less than the anticipated level. If the product price does not decline, the quantity of capital remains unaffected. Insofar as it does decline, it must be because the same amount of free and available resources as that used under the old method can be used under the new method to produce more product and force the decline in price. The decline in price indicates that more is being produced, and since the decrease in quantity of capital takes place only because of this decline in price, then the decrease in quantity is no loss to the society since it is more than offset by gains in efficiency. Obviously, there is no gain to be realized from slowing the introduction of inventions where prices respond properly to real factors, even though the quantity of capital may decline to less than that which would have continued to exist if the invention had not been introduced (assum-

ing we do not include in the quantity of capital the value of the available technological knowledge).

Once investments are made on the basis of wrong predictions, the situation cannot be remedied for the social good except by more intensive use of the investments most subject to obsolescence. From the point of view of the individual investor, the sooner he learns of this adverse selection, the sooner he can unload on someone else. If others are aware of the situation, then his only alternative is to work the investment harder and attempt to sell as much of its services as possible before the price of its services is weakened. All investments cannot be worked harder at the same time, however, unless there is an unused supply of complementary factors which can be brought forth for such a purpose. If the incidence of technological change on some types of equipment is known sufficiently far in advance to be greater than on other types, some capital which might otherwise be lost can be saved by transferring variable resources from the least vulnerable equipment to the most vulnerable. Beyond this, nothing can be done from the social point of view to rectify the consequences of decisions which, after they are put into effect, are discovered to be erroneous in the light of revised knowledge of the future. Much can be done from the point of view of the individual losers, but if it is permitted it will be to the social detriment.

